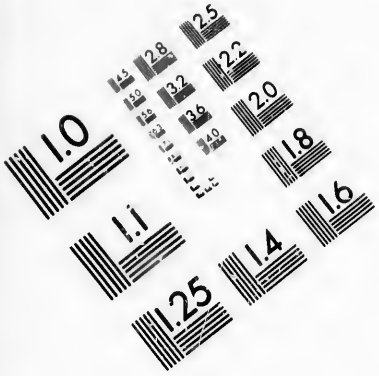

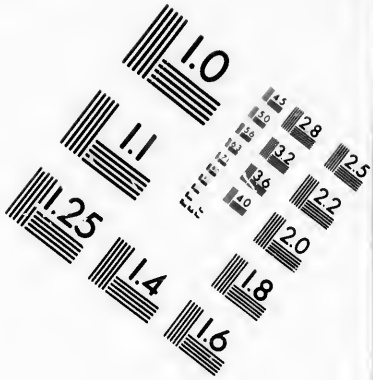

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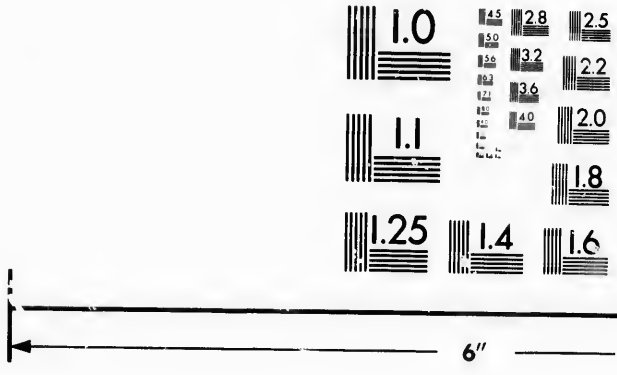

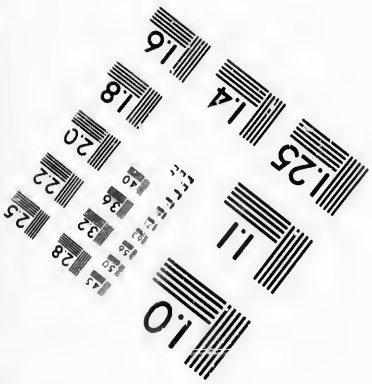

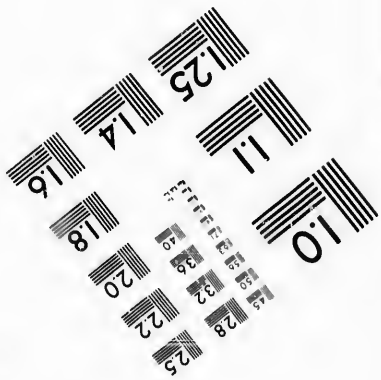

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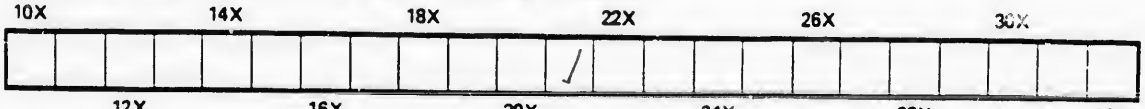

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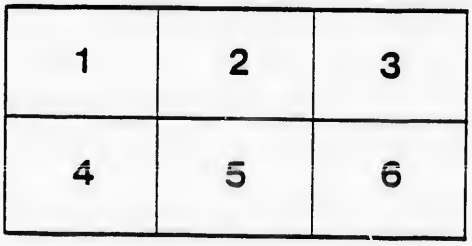

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CLASSIFICATION OF THE CAMBRIAN SYSTEM OF NORTH AMERICA.

By C. D. Walcott.

[From the American Journal of Science, Vol. XXXII, August, 1886.]

Art. XVI.—*Classification of the Cambrian System of North America;** by Charles D. Walcott.

The formations included within the Cambrian system, in this paper, are those characterized by the predominence of the types of the "First Fauna"† of Barrande and such additional

* Read before the National Academy of Science at Washington, D. C., April 23d, 1886.

† The "First" or "Primordial Fauna" of Barrande, as found in North America, is characterized by a trilobitic fauna which, in the presence of the genera Agnostus, Paradoxides, Olenellus, Dicellocephalus, Ptychoparia and their allied genera, distingnishes it from the succeeding Lower Silurian (Ordovician) fauna.

strata, not characterized by the presence of fossils, as are stratigraphically and structurally connected with Cambrian strata identified by organic remains.

Professor Geikie, in the last edition of his Manual of Geology (1885, p. 65), has included the Cambrian as a subdivision of the Silurian system. I do not *now* wish to question the wisdom of this for the geologic section as it occurs in England and the Continent; but of the presence of a well-defined geologic system beneath the Lower Silurian (Ordovician) strata characterized by the Second fauna of Barrande, or the Trenton fauna (including the Upper Calciferous) on the North American continent, there is little doubt. The geologic sections, given in this paper, show that it has a total thickness of over 18,000 feet and contains a known fauna of 92 genera, including 393 species; that but very few of these species pass up into the Calciferous horizon of the Lower Silurian (Ordovician), and that the faunas of the two systems are so distinct in their general facies and also in detail, that they are quite as readily separated as the Lower and Upper Silurian, Silurian and Devonian, or Devonian and Carboniferous faunas. There is no doubt that in certain areas the faunas of the Cambrian and Lower Silurian (Ordovician) systems are intermingled in the passage beds between the two systems, but the same is more or less true of all the great divisions of the entire geologic series, from the Archean to the Quaternary.

Strata of the Cambrian System.

In beginning the study of the Cambrian system, I looked for well-defined Paleontologic horizons with relation to which the various local sections and their contained faunas could be compared. It was evident that the Potsdam faunas of New York and the Mississippi Valley were at or near the summit of the Cambrian, but further than that there was little data. Mr. E. Billings called the Georgia or Olenellus fauna "Lower Potsdam," and considered the Paradoxides fauna as of older date: but, as late as 1885, one of our best-known paleontologists wrote: "my own impression, at the present, is that the New York typical Potsdam is about equivalent to the lower portion of the Wisconsin areas, and that the Acadian beds of Canada and Vermont, and perhaps the other Atlantic areas, are not appreciably different in age, but that the difference in faunas is more the result of conditions upon which life depended than a difference in time." (Bull. Amer. Mus. Nat. Hist., vol. i, p. 140, 1885.)

The results of the study of the Middle Cambrian faunas will appear in Bulletin 30, of the U. S. Geological Survey, and I have taken much of the data of this paper from the introduc-

tion of that bulletin. In establishing the stratigraphic position and paleontologic characters of the Georgia or Olenellus fauna of the Middle Cambrian, the key to the succession of the Cambrian faunas was obtained, and the sections that are correlated

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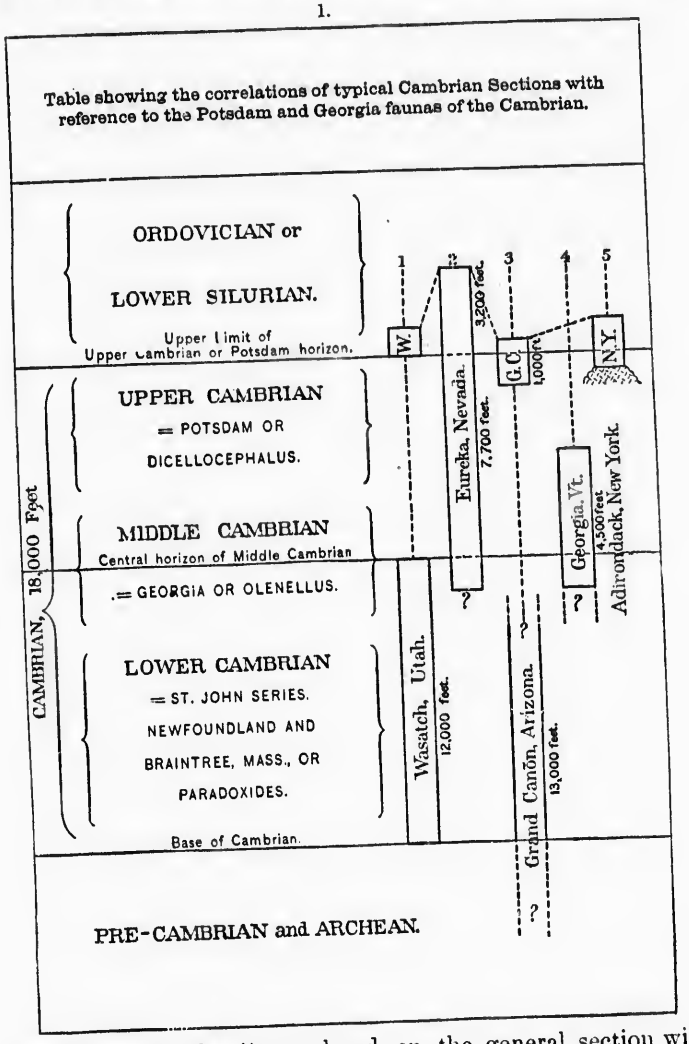

in the diagram (fig. 1) are placed on the general section with relation to the stratigraphic position of Olenellus and Dicellocephalus, or Georgia and Potsdam faunas.

The first section (fig. 2) to which I wish to direct your attention is that of the Wasatch Mountains, in Utah, where the Cambrian is well shown in Big Cottonwood Cañon. The section is described in the reports of the Geologists of the

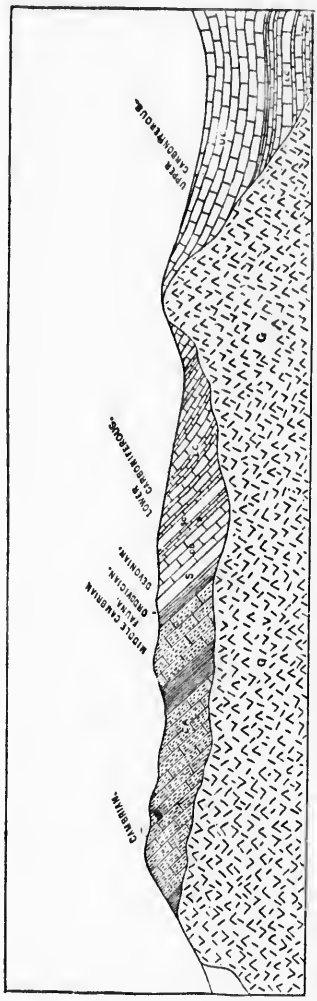

Fig. 2.—Wasatch section. This crosses the Wasatch Mountains a little south of Big Cottonwood Cañon. Copied from map of sections accompanying vol. i, Geol. Expl. of Fortieth Parallel. Scale, about 10,000 feet to the inch. The Cambrian strata are represented as resting unconformably on the granite and as overlaid by the conformable Lower Silurian (Ordovician) strata. The position of the Middle Cambrian fauna is indicated just below the Silurian horizon. CA, Cambrian; S, Silurian; OD, Devonian; LC, Lower Carboniferous; UC, Upper Carboniferous; G, Granite. Further study in the field will probably result in a somewhat different representation of this section, as it was originally based on rapid reconnaisance work by the geologists of the Fortieth Parallel Survey. The relations between the granite and the overlying strata are not as understood by myself, but are given as in the original section.

Fortieth Parallel Survey (Geol. Expl. 40th Par., vol. i, p. 229; vol. ii, p. 366), but I had the opportunity of examining it more in detail during the summer of 1885, and through finding the

Olenellus or Middle Cambrian fauna, located its upper horizon and ascertained that the entire Upper Cambrian was absent by non-deposition, the Silurian resting conformably on strata of Middle Cambrian age. The section at the base rests on granite near

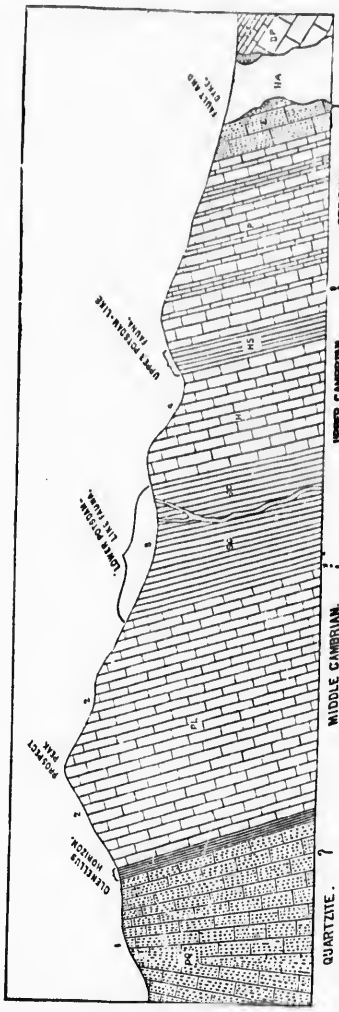

Fig. 3.—Eureka section. This extends over the Cambrian strata of the Eureka district and up to the base of the Trenton limestone horizon of the Lower Silurian (Ordovician). The numbers on the upper line correspond to the numbers on the divisions given in the descriptive section: 1 and PQ, Prospect Mountain quartzite; 2 and PL, Prospect limestone; 3 and SC, Secret Cañon shale; 4 and 11, Hamburg limestone; HS, Hamburg shale; P, Pogonip limestone; E, Eureka quartzite; HA, hornblende-andesite; LC, Lower Carboniferous; DP, Devonian. The dike represented in the Secret Cañon shale is not continuous, and on the line upon which the fossils were collected it was not observed, the section being unbroken from 1 to the great dike beyond the Eureka quartzite. The section is copied from the unpublished map of sections, by Mr. Arnold Hague, illustrating the Geology of the Eureka district. Scale, 1,800 feet to the inch.

the mouth of Big Cottonwood Cañon, and the strata continue up the cañon in an unbroken, conformable series of siliceous rock, shales, quartzites and sandstones, until 12,000 feet in thickness

is passed through. In the upper 250 feet of silico-argillaceous shales that rest on a massive band of quartzite, 3,000 feet in thickness, the following fossils occur: *Cruziana?*, *Lingulella Ella*, *Kutorgina pannula*, *Hyolithes Billingsi*, *Leperditia Argenta*, *Olenellus Gilberti*, *Ptychoparia quadrans* and *Bathyuriscus producta*. This fauna is also found at a similar horizon in several localities in Nevada; and the lithologic, stratigraphic and paleontologic evidence, as found in the Oquirrh and Tintic ranges of Utah and the House, Eureka and Highland ranges of Central Nevada, extends the same horizons throughout the western and southern portions of the Great Basin area.

The entire absence of fossils in the lower portions of the Wasatch section may be owing to the character of the sediments; but an attempt is made further, to explain the absence of the Lower Cambrian fauna of the Atlantic area.

The second section (fig. 3), that of the Eureka District, by Mr. Arnold Hague, stratigraphically overlaps that of the Wasatch, the lower 1,500 feet of quartzite corresponding to the upper-half of the 3,000 feet of quartzite of the Wasatch section, and the Olenellus shales occurring at the same horizon on the summit of the quartzite; but here the Lower Silurian (Ordovician) strata do not rest on the siliceous Olenellus-bearing shales, but are separated by over 6,000 feet of limestone that carries a fauna uniting the Middle Cambrian fauna with the Upper Cambrian or Potsdam fauna, which begins in its characteristic forms 4,500 feet above the Olenellus horizon. One hundred miles south of Eureka, in the Highland Range, I found the Eureka section essentially repeated and identical species occurring at the same relative horizons in each section. The vertical range of the Eureka section embraces the corresponding strata of the Highland Range section and several sections that occur in Nevada and Western Utah.

Section No. 3, fig. 4, is unlike either of the first two sections in having the Upper Cambrian well developed, and the Middle, and probably the Lower Silurian (Ordovician), entirely absent. This section is beautifully exposed in the deeper portions of the Grand Cañon of the Colorado, Arizona, and was first made known in a general way, through the explorations of Major J. W. Powell in 1875. During the winter of 1882–83, Major Powell instructed me to make a detailed section of the strata in the depths of the cañon, and fig. 4 is one of the results of the work. The Upper Cambrian, or Tonto formation is 1,000 feet in thickness, composed of siliceous and calcareous strata and carries a fauna that unites it closely with that of the Upper Cambrian of Nevada, Texas and the Upper Mississippi Valley. Beneath the Tonto there is a great mass of strata, over 12,000 feet in thickness, that are unconformable to the horizontal Tonto

strata above and the highly-inclined (Huronian?) strata beneath. I have heretofore referred the pre-Tonto series to the Cambrian and correlated it with the Keweenaw of Wisconsin and Llano series of Texas, but I am now inclined to call all these series

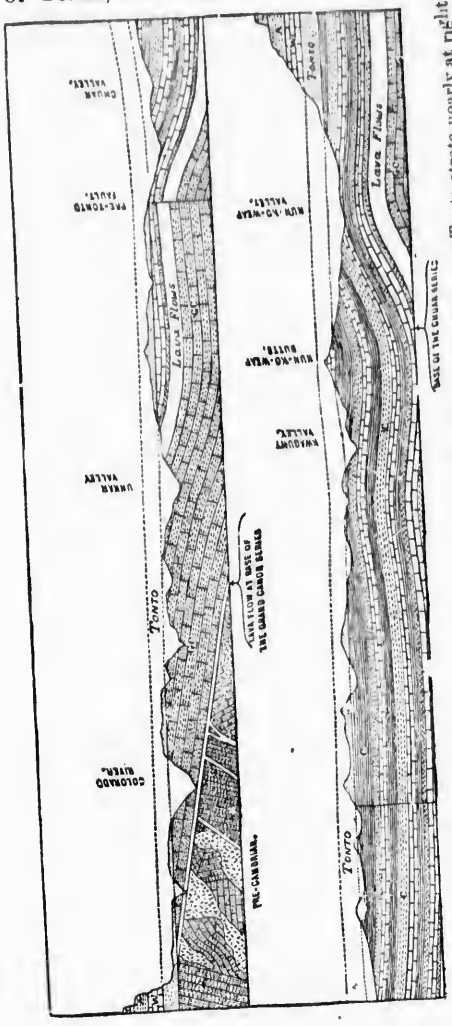

Fig. 4.—Grand Cañon section. The section represented by this figure crosses the pre-Tonto strata nearly at right angles to their strike as exposed in the Grand Cañon of Colorado, Arizona, and studied by the writer. Horizontal scale, 12,500 feet to the inch. Vertical scale about 8,500 feet to the inch. The Upper Cambrian (Tonto formation) has been removed by erosion on the direct line of the section, but is present, as indicated by the dotted lines, around the margins of all the cañons that cut it on the line of the section. GC, Grand Cañon formation (the lava flows also belong to this); T, Tonto formation; W, Red Wall Carboniferous limestone; A, Aubry Carboniferous sandstone (above this comes the Aubry Carboniferous limestone, which forms the outer wall of the canon). All the strata beneath the Tonto formation are considered as pre-Cambrian.

pre-Cambrian and a system of equal degree with the Cambrian, Lower Silurian (Ordovician), etc. If this is done the strata below the Grand Cañon series will be correlated with the Huronian of the Wisconsin section. This will be referred to again.

The Grand Cañon section is typical and includes with it the Cambrian section of Central Texas and Northern Wisconsin (see figures 5, 6).

Crossing to the eastern side of the Continent, our next section (fig. 7, p. 148) of the Cambrian strata is taken in Northwestern Vermont, and its contained faunas serve to connect the distant Nevada sections and the group of Cambrian sections along the St. Lawrence, Champlain, and Hudson River Valleys.

At the base of the section a massive belt of limestone, 1,000 feet in thickness, carries in its upper portions the Olenellus fauna which, in the argillaceous shales capping the limestones, attains an extensive development. Continuing up in the section through the argillaceous shales, about 2,000 feet, masses

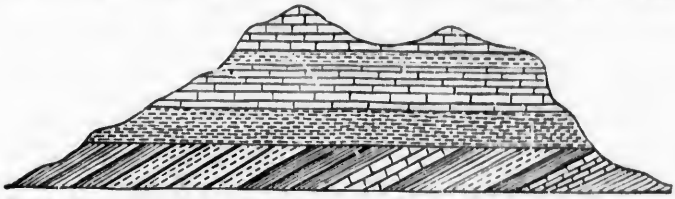

Fig. 5.—Section in Llano County, Texas, showing the relations of the Upper Cambrian (Potsdam) and the pre-Cambrian Llano Series.

of limestones are found interbedded in the shales, and in the limestone fossils that show the near approach of the Upper Cambrian or Potsdam fauna. The section gives the same succession of fauna as the sections of Nevada, where we find positive stratigraphic proof of the great difference in age of the Middle and Upper Cambrian faunas.

The Georgia, Vermont, section includes, in its vertical range, the sections about and below Troy, N. Y., in the Hudson River Valley, and those of Northwestern Newfoundland and the Straits of Belle Isle.

Directly east of the Adirondack Mountains of New York, the Potsdam sandstone is overlaid by a stratum of shaly arenaceous rock full of fucoidal, or annelid markings, and there the Chazy limestones appear resting on the latter.* Tracing the sandstones south, a fine exposure is seen at Ausable Chasm, and continuing south a limestone is found coming in on top of the sandstone that, in Saratoga County, contains a well-marked fauna of twelve species, four of which are identical with species in the upper beds of the Wisconsin Potsdam sandstone. The calcareous layers of the Potsdam also occur at Whitehall, and Professor Dwight has found them near Poughkeepsie.

* The unconformity, by non-deposition, noticed by Sir William Logan, is nowhere better illustrated than at this point, the Calciferous formation being absent from the section.

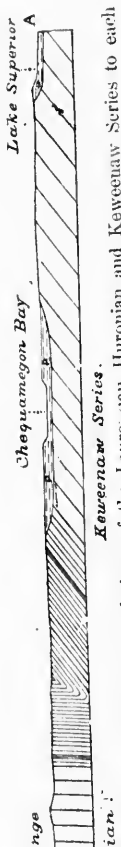

Fig. 6.—Section in Northern Wisconsin showing the relations of the Laurentian, Huronian and Keweenaw Series to each other and to the overlying Upper Cambrian (Potsdam) strata.

During the deposition of the Potsdam sandstone the shore-line was close at hand, and the Adirondack area furnished material for the formation. Out from the shore-line the mud and sand were mixed, and still farther out, over the present area of the Georgia section, the shales with interbedded limestones point to deeper, quieter waters. I have yet failed to find in Vermont any Potsdam sandstone north of Burlington; and the evidence goes to prove that the upper portion of the Georgia section, with its shales and "lentiles" of limestone, is equivalent to the Potsdam sandstone about the Adirondacks.

We have now hastily reviewed the principal sections of the Cambrian under which all the others now known can be grouped except those of Braintree, Massachusetts, St. John, New Brunswick and the southeastern Newfoundland sections. These are not connected paleontologically with the more western section and we distinguish them as the Atlantic border sections, and mostly of older date* than the strata of all but the lower portions of the Wasatch, and perhaps the Tennessee sections. As the position of the Atlantic border Paradoxides fauna is determined on paleontologic evidence, the discussion of it will be taken up later.

In the following table, the writer expresses his view of the classification of the various formations that go to make up the Cambrian system of North America. It is subject to revision in details, but the main divisions are based on paleontologic and stratigraphic data, that I think will render them of service in the permanent classification of American Paleozoic rocks.

It is not claimed that the arrangement of the formations in the following table is original with me, as, with some changes in nomenclature, it is the same as that to be found on page 46 of the Report of the Geological

* At St. John, New Brunswick and also in Newfoundland, the higher members of the Cambrian system, containing the later Cambrian faunas are known, but, with our present information, the lower fauna predominates, and the upper faunas will probably prove to be more closely related to the Atlantic than to the interior basin, although we may expect to find a number of species common to each.

Classification of North American Cambrian Rocks.

	Lower Calciferous.	Lower portion of the Calciferous formation of New York and Canada. Lower Magnesian of Wisconsin, Missouri, etc.
UPPER CAMBRIAN.	Potsdam, Knox, Tonto.	Potsdam of New York, Canada, Wisconsin, Texas, Wyoming, Montana and Nevada: Tonto of Arizona; Knox Shales of Tennessee, Georgia and Alabama. The Alabama section may extend down into the Middle Cambrian.
	Georgia.	Georgia formation of Vermont, Canada and New York.
MIDDLE CAMBRIAN.	L'Anse au Loup.	Limestones of L'Anse au Loup, Labrador.
	Prospect.	Lower part of Cambrian section of Eureka, and Highland Range, Nevada. Upper portion of Wasatch Cambrian section, Utah.
	St. John, Braintree, Newfoundland, Wasatch.	Paradoxides beds of Braintree, Mass., St. John, New Brunswick, St. John's area of Newfoundland, Lower portion of Wasatch section, Utah.
LOWER CAMBRIAN.	Tennessee.	The Ocoee conglomerate and slates of East Tennessee are doubtfully included.

Survey of Newfoundland for 1865, published in 1866, by Sir William Logan, and based largely on the paleontological work of Mr. E. Billings.

Fauna of the Cambrian System.

As has long been well known, the Trilobita form by far the largest portion of the Cambrian fauna. Of the ninety-two genera and three hundred and ninety-three species known to me at present from the American Cambrian, 31 genera and 226 species are placed under the Trilobita, and 61 genera and 167 species under all the other classes. The Brachiopoda come next with 15 genera and 67 species; Crustacea with 10 genera and 15 species, etc.

In the accompanying table a summary is given of the Cambrian faunas of North America, as far as known to me, up to the present date. A critical study of the Upper Cambrian faunas will eliminate some of the genera and species and, also, add others. The study of the Lower Cambrian fauna of New Brunswick is now being carried forward by Mr. G. F. Matthew, and that of the Upper Cambrian by myself; and probably within two years the Cambrian fauna of North America will include more than 100 genera and 400 species, as to-day there are 92 genera and 393 species published, that I have included in the fauna. There are a number of genera and species not included that do not appear to be based on organic remains, or are synonyms of some of those that are included.

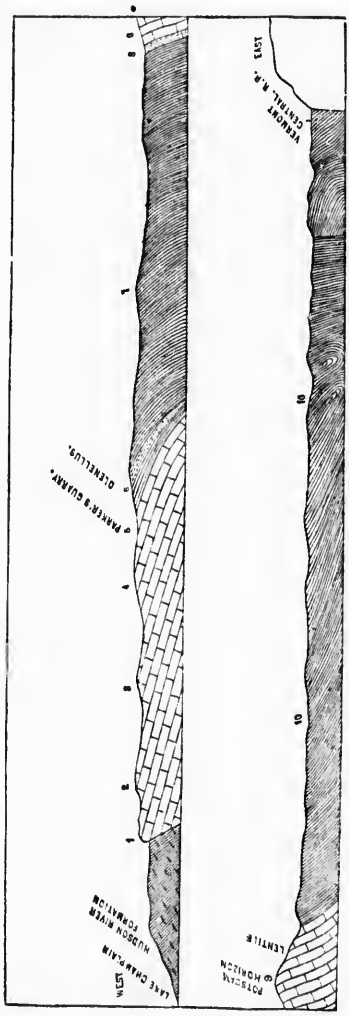

Fig. 7.—Georgia section. This extends from Lake Champlain east to the Vermont Central Railroad track, and passes through the Parker trilobite quarry, and a little south of the town of Georgia post office. Horizontal scale, about 2,000 feet to the inch.
The figs. 1 to 10 indicate the position of the lower strata of each of the divisions given in the descriptive section.

Geologic Résumé.

	Genera.	Species
Upper Cambrian	52	213
Middle Cambrian	43	107
Lower Cambrian	32	76
	127	396
Reappearances	35	3
Total fauna	92	393

Zoologic Résumé.

	Genera.	Species.
Algæ	3	9
Spongiæ	6	13
Hydrozoa	4	5
Crinoidea	1	3
Annelida	2	5
Brachiopoda	15	67
Lamellibranchiata	1	1
Gasteropoda	14	29
Pteropoda	5	20
Crustacea	10	15
Pœcilopoda	31	226
	92	393

There are 14 genera common to the Lower and Middle Cambrian; 15 common to the Middle and Upper Cambrian; 11 common to the Lower, Middle and Upper Cambrian, and 12 common to the Lower and Upper Cambrian.

Of the 52 genera in the Upper Cambrian, 17 are much more strongly represented in the second fauna, viz: Lingula, Orthis, Leptæna, Triplesia, Bellerophon, Euomphalus, Holopea, Maclurea, Metoptoma, Ophileta, Pleurotomaria, Hyolithes, Serpulites, Amphion, Bathyurus, and Ogygia.

Of the above genera, Discina, Pleurotomaria, Amphion, Bathyurus and Ogygia are doubtfully referred to the Cambrian. Several other genera pass up into the base of the Lower Silurian (Ordovician), but are not considered as at all characteristic of its fauna.

When an accurate stratigraphic and paleontologic study is made of the passage beds between the Cambrian and Lower Silurian (Ordovician) systems, or the Potsdam and Upper Calciferous formations of the New York and Canadian sections, we shall possess the data upon which to compare the faunas of the two systems. At present it is to a large extent wanting.

Stratigraphic position of the Upper, Middle and Lower Cambrian Faunas.—That the stratigraphic position of the Middle Cambrian fauna on the North American continent is below that of the Potsdam fauna is shown by the Eureka and Highland Range sections, in Nevada, and the Georgia section, in Vermont. In Nevada, in two sections unbroken by faulting or folding of the strata and separated by a geographic distance of one hundred and twenty-five miles, the fauna ranges from 2,000 to 4,000 feet below strata carrying a typical Upper Cambrian, or Potsdam fauna. But three species, *Protospongia fenestrata*, *Acrotreta gemma* and *Stenotheca elongata* are known to pass up to the Upper Cambrian or Potsdam horizon. In the Georgia, Vermont, section, one of the species, *Ptychoparia*

Adamsi appears to pass up into the Potsdam horizon of the section, where the fauna is more like that of the Potsdam; and of the other species, *Orthisina Orientalis* is much like *O. Pepina* of the Potsdam sandstone of Wisconsin: but the fauna, as a whole, is so clearly distinct from the typical Potsdam of New York, Wisconsin, Tennessee, Alabama, Texas, Arizona, Nevada and Montana that, even without any section to show their relations to each other, I should not think of correlating them as contemporaneous faunas.

The stratigraphic relations of the Middle Cambrian fauna to the Paradoxides fauna of St. John, Braintree and Newfoundland are not so clearly proven as for the Middle, and Upper Cambrian faunas. The only locality known where the two faunas are in the same geographic area is about Conception Bay, Newfoundland. At Topsail Head about 100 feet of limestone is exposed, overlaid by dark shale. All stratigraphic connection with other sections in the vicinity is broken. The fossils in the limestone are not numerous, but Mr. Billings pronounced them Potsdam (Geol. Newfoundland, p. 158, reprint of report for 1868), and identified *Salterella*, *Crania* (probably *Kutorgina*) *Labradorica*, and I found, in the collection of the Geological Survey of Canada, *Scenella reticulata*, *Stenotheca rugosa*, *Iphidea bella* and *Protypus senectus* var. *parvulus*, which gives six species that are also known from the Middle Cambrian horizon of L'Anse au Loup.* Special stress is placed by the writer on the occurrence of these fossils at Topsail Head, as it is in the midst of the Paradoxides basin. Mr. Alexander Murray correlated the Topsail Head limestone with that of other localities, and places it beneath the Paradoxides-bearing shales of St. Mary's Bay (on the page cited above), but without paleontologic or stratigraphic evidence that can authorize him to say more than that a supposed connection is indicated.

Not having stratigraphic evidence of the relation of the Georgia or Middle Cambrian fauna and the Paradoxides or Lower Cambrian (Ordovician) fauna other than that they occur in the same area and are not in the same stratum of rock, we turn to the faunas to aid us in the settlement of the question.

Of the thirty-two genera of the American Paradoxides horizon, fifteen pass up into the Olenellus horizon, viz: Arenicolites, Protospongia, Archæocyathus?, Eocystites??, Lingulella, Acrotreta, Acrothele, Kutorgina, Orthis, Stenotheca, Hyolithes, Agnostus, Microdiscus, Solenopleura, and Ptychoparia. Of these, eleven, Arenicolites, Protospongia, Lingulella, Kutorgina, Acrotreta, Orthis, Hyolithes, Stenotheca, Agnostus, Microdiscus? and Ptychoparia, continue on up into the Potsdam or

* Mr. Billings called all the Middle Cambrian fauna "Lower Potsdam," which explains his referring the Topsail Head fossils to the Potsdam.

Upper Cambrian horizon, leaving but four genera that are alone common to the Middle and Lower horizons. One genus, Dendrograptus, is doubtfully identified in the Paradoxides horizon of New Brunswiek that occurs in the Upper Cambrian, and is, as yet, unknown in the Middle Cambrian. The genus Agraulos is also found in the Lower and Upper, but not in the Middle Cambrian. Of species, not one of the 76 of the American Lower Cambrian fauna are known to occur in the Middle Cambrian fauna, which, with its 107 species, stands out clearly from the older fauna and also from the more recent Potsdam fauna, as but three of its species, *Protospongia fenestrata*, *Stenotheca elongata* and *Acrotreta gemma*, are known to occur in the Upper Cambrian, and 16 of the genera in the Middle Cambrian are not known to pass up into the Upper Cambrian or into the Lower Silurian (Ordovician) faunas. Not one species is known to be common to the *Lower* and *Upper* Cambrian horizons.

Having studied the Middle Cambrian fauna more thoroughly than that of the lower and upper horizons, I will speak of it on that account and, also, from the fact that its character and geographic distribution is not as well known as the other two.

As a whole, we notice that it combines the characters of the Lower Cambrian and Upper Cambrian faunas and yet is distinct from each of them. There does not appear to be an equivalent fauna in the Cambrian system of Europe either in Bohemia, the Scandinavian area, or in Wales; but from the Island of Sardinia, Dr. Bornemann has described a group of sponge-like bodies closely related, if not identical with *Ethmophyllum* and *Archæocyathus* of the American Middle Cambrian fauna; he also names *Kutorgina cingulata* which is found at this horizon both in Vermont and Labrador. A species of trilobite is referred to Olenellus, but I have not seen any illustration of it.

The conditions that developed the Middle Cambrian fauna appear to have been largely peculiar to the American continent. During the deposition of the St. John's series of the Lower Cambrian, or the Paradoxides strata, we learn from the European and Eastern American sections, that the fauna was essentially of the same type over the entire basin (Atlantic), and, from evidence known to date, that the fauna did not extend west of a line passing northeast through Eastern Massachusetts to New Brunswiek and Newfoundland.

That there were deposits of sediment to preserve the fauna, if it extended westward, is shown by the thousands of feet of sediments below the Middle Cambrian faunas of Utah and Nevada.

From the data we now have, I think that during the exist-

ence of the greater portion of the Lower Cambrian (Paradoxides) fauna, a barrier existed that prevented its extension westward of the line mentioned; that towards the close of the time of the Paradoxides fauna that barrier was removed to the northeast, in the vicinity of Newfoundland, and the descendants from the Paradoxides fauna entered the westward seas and spread to the eastern and western basins and formed the Middle Cambrian fauna. What route was taken by the Middle Cambrian fauna after passing to the western side of the outer barrier is not yet traced, but I think from the indications we now have of a continental area, during Lower and Middle Cambrian time, in the central portion of the continent, that the fauna passed to the south around the southern end of the then existing land, and thence north along the west shore. In the Atlantic basin, the Paradoxides fauna persisted to a greater or less extent and mingled with the types of the Upper Cambrian fauna as in the Upper Lingula Flags of Wales.

If this is a correct interpretation of the evidence now known, we may look in vain in the central interior basin for the Paradoxides fauna of the Atlantic basin.

That there was life in the older Cambrian or pre-Cambrian seas of the central interior basin, there is no doubt, as we have found traces of it in the Grand Cañon section of Arizona; and the development of that fauna which from the stratigraphy is pre-Cambrian, is one of the problems awaiting solution.

During the Upper Cambrian (Potsdam of America; Upper Lingula Flags of Wales), the Atlantic and Pacific basins appear to have had free communication with each other, and the faunas now have a facies of the same general character.

The above views are, to a certain extent, theoretical, but the facts demand an explanation other than that the faunas of the Lower, Middle and Upper Cambrian were contemporaneous but in different geographic areas. That the upper and middle faunas were separated by a great interval, is shown by the sections in Nevada and Vermont; and that the middle and lower faunas were not contemporaneous is shown by the biologic evidence and the indirect evidence of the absence of the lower fauna in association with the middle fauna in the Newfoundland area, where they are now found in different strata, but a short distance from each other.

A diagram illustrating the Cambrian sections of America and Europe would show, in the former, that the sequence of life is divided more sharply into three great groups that, in the latter, are more or less broken up. First: by the nearly entire absence of the middle group, and secondly, by the commingling of the upper and lower groups in the European strata and possibly in the Atlantic border sections of New Brunswick and

Newfoundland. This subject will be treated in detail after the completion of the study of the Upper Cambrian faunas now in progress.

As previously mentioned, I have heretofore included the Grand Cañon and Llano series as, in part, of Cambrian age, and correlated them with the Keweenaw series (Bull. VI, Phil. Soc. Washington, p. 102, 1882). In adopting the view that all of these may be placed under a system of pre-Cambrian age, I think there is good reason for it in the presence of the great unconformity, by erosion, between the strata of the Keweenaw system* and the known Cambrian formations. An examination of the sections shows that in each of them there is a great series of disturbed and eroded strata overlaid by the horizontal beds of the Upper Cambrian; and in the Keweenaw, and the Grand Cañon sections, this great series of strata is in turn separated from the formation below by an unconformity that, in the Grand Cañon, is very great, and in the Lake Superior area, sufficient to indicate an orographic movement previous to the deposition of the Keweenaw strata. All three of the sections (figs. 4, 5, 6) agree in the evidence of an extended orographic movement and a great period of erosion at the close of deposition of the Keweenaw series; and I am now of the opinion that the Keweenaw system should be considered as pre-Cambrian. The correspondence in the position of the pre-Grand Cañon strata, separated from the Grand Cañon series by a great unconformity, to the Huronian as described by Irving, is so striking that more than calling attention to it is unnecessary.

The presence of organic remains does not necessarily imply that the strata are of Cambrian age except they show a marked Cambrian facies; and unless this is the case I should not contend for a moment against well-proved stratigraphic evidence of greater age and marked structural breaks in the stratigraphic succession. It may be asking too much for the period of erosion, between the Keweenaw system and the Upper Cambrian, to say that 12,000 feet of mechanical sediments and 4,000 feet of limestone accumulated in the Utah-Nevada basin while this erosion was taking place; but, if we look higher up in the Grand Cañon section, and that of Central Nevada, we find that 200 feet of Silurian and Devonian strata in the former is repre-

* The Keweenaw system is here used to include the Keweenaw series of the Lake Superior region, the Llano series of Texas and the Chuar and Grand Cañon series of the Grand Cañon of the Colorado, Arizona, and is considered as of equal value with the Cambrian, Lower Silurian (Ordovician), Upper Silurian and other systems of the Paleozoic Group, and as belonging to the Paleozoic rather than to the Archean. It may be that the Keweenaw and Grand Cañon series belong to distinct systems of strata, but until this is proven I prefer to provisionally refer them to a pre-Cambrian post-Huronian system. I think the Grand Cañon and Llano strata belong to one system.

sentative of the 13,000 feet of limestone of the same formations in Nevada, and no unconformity, by any extensive erosion, is indicated; and, again, the 9,000 feet of limestone of the Upper Cambrian and Lower Silurian (Ordovician) of the Central Nevada section is unrepresented in the Wasatch section of Utah. These facts readily prepare us to believe that the hiatus between the Keweenaw and Upper Cambrian is fully equivalent to the period of the Lower and Middle Cambrian.

Another reason is that from the extended orographic movement preceding the erosion of the Cambrian, we should expect to find evidence of that erosion in the Cambrian of Utah and Nevada, but, as yet, none such is known.

Thus far the question of the existence of the Keweenaw system has been treated from a purely structural basis,* but, in the course of my study of the distribution of the Cambrian faunas, I have met with some facts that require an explanation and the most plausible one demands the existence of an extended orographic movement, prior to the deposition of the Cambrian strata of the western side of the Continent, that raised a land area over the central portion of the Continent which existed up to the period of the beginning of the deposition of the Upper Cambrian formations, when it was depressed beneath the level of the sea and the Upper Cambrian strata deposited over portions of it.

The facts demanding explanation are: 1st. The entire absence, as far as known to date, of the Lower Cambrian or Paradoxides fauna west of the Atlantic border: 2d. The absence of the Middle Cambrian or Olenellus fauna over areas occupied by the formations of the Keweenaw system.

If we accept the view that the Keweenaw, Grand Cañon, and Llano strata are outcrops of a system of strata of pre-Cambrian age that extended, in connection with the Huronian and Laurentian beneath it and projecting up through it, from the great body of Archean land on the north, southward over the area now occupied by the central portions of the Continent, or the Mississippi Valley, and westward to the area occupied by sediments accumulated on the western side of the Keweenaw system of strata when the latter formed a land area, then the explanation asked is given. The pre-Keweenaw portion of this Keweenaw land must have been extensive as, in the Missouri area at St. Louis and the Ozark Mountains, the Archean appears beneath the Upper Cambrian; and all the eastern slopes

* Professor T. C. Chamberlain gives a most excellent summary of the Keweenaw series and its stratigraphic position in vol. i, of the Geology of Wisconsin. In the section, on page 65, it is placed as a distinct system, resting unconformably on the Huronian which, in turn, is separated from the Laurentian by an unconformity. The Cambrian is shown above the Keweenaw as a system between it and the Lower Silurian (Ordovician).

of the Rocky Mountains of Colorado show only the thin Upper Cambrian formations resting on the Archean; and the same is true in the Black Hills and in Central Wyoming. The

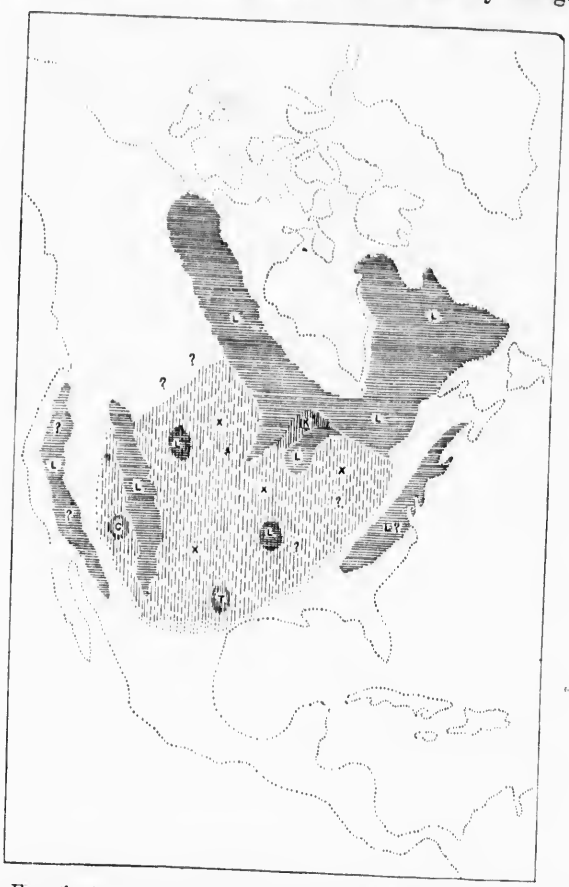

Fig. 8.—Hypothetical map showing the supposed Keweenaw land or continent as it existed just before the deposition of the Upper Cambrian (Potsdam) sediments. The latter probably extended over most of the area marked X, X, X, although now concealed by the later sedimentary deposits. The age of the eastern and western belts, marked L?, is still in doubt, but the presence of the eastern belt is strongly indicated by the geographical distribution of the Cambrian faunas. L, Laurentian and other Archean formations; K, Keweenaw; T, Llano formation; C, Grand Cañon formation; X, X, X, area supposed to have been land surface but now concealed by later deposits.

existence of these Archean areas with the Upper Cambrian deposits proves the early date of their elevation, and that they

were the shore line of the pre-Cambrian Keweenaw sea. What the eastern boundaries of this sea were, we do not now know, but the inference, from what is known of the Archean of the Appalachian system, is that portions of the latter were above the ocean during the deposition of the Keweenaw system.

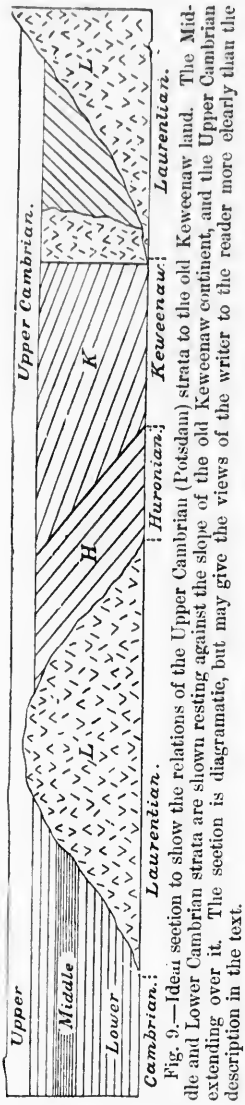

Fig. 9.—Ideal section to show the relations of the Upper Cambrian (Potsdam) strata to the old Keweenaw land. The Middle and Lower Cambrian strata are shown resting against the slope of the old Keweenaw continent, and the Upper Cambrian extending over it. The section is diagramatic, but may give the views of the writer to the reader more clearly than the description in the text.

The traces we now have of this Keweenaw land point to its extension from the Lake Superior region south to Central Texas and westward to Central Northern Arizona. A glance at the map (fig. 8) shows how far apart the relatively small exposures are; but, the great similarity of the sections and their position in relation to the Upper Cambrian that rests on the eroded surface of each visible area, points to a wide spread orographic movement that raised the entire central portion of the Continent and again depressed it at the termination of the period of erosion preceding the deposition of the Upper Cambrian or Potsdam sediments of the Upper Mississippi Valley, Central Texas and Arizona.

The existence of such a land over the area mentioned, is shown by the sections we now know; and I think that, when the areas of Cambrian and Archean rocks in Missouri and also along the Southern Appalachian chain come to be studied with the view that such a land existed during the period of the deposition of the earlier deposits of the Cambrian system, evidence will be forthcoming to show its former presence over a large area. On the north it probably joined the Archean continent and thus gave a greater extension of the pre-Cambrian continent to the south that, during the early history of the Cambrian period, furnished more or less of the sediments of the strata of the Lower and Middle Cambrian. The Archean boundaries of the Keweenaw sea continued after the elevation

of the Keweenaw land. When Keweenaw land is spoken of, I refer to that formed of the strata of the Keweenaw system and the Archean rocks with which it was associated.

Before the Keweenaw land was depressed the Middle Cambrian fauna passed through or around the barriers between the Atlantic and western seas, and, as the Keweenaw land was disappearing beneath the waters, the Upper Cambrian fauna spread over the area occupied by it and left its record to aid us in fixing the geologic date of the submergence of the Keweenaw land and to explain the absence of the Paradoxides or Atlantic fauna in the early Cambrian strata of the western side of the Continent. In the diagramatic section (fig. 9), I have endeavored to show the relations of the Potsdam or Upper Cambrian to the Keweenaw land.

The evidence of the existence of the Keweenaw land is both stratigraphic and paleontologic. That life existed in the seas at the time of the deposition of the sediments of the Keweenaw system, is shown by its presence in the Chuar formation of the Grand Cañon series.

It may be urged that there is too much theorizing, on insufficient data, in the preceding statements, but, while waiting the accumulation of evidence it is well to have a working theory and as such the "pre-Cambrian Keweenaw land" is proposed, and the fragmentary remains, less the Archean portions, called a "pre-Cambrian Paleozoic System."